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Can Agricultural Citizen Science Improve Seed Systems?

The contributions of crowdsourcing participatory variety selection through on-farm triadic comparisons of technologies

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Front cover image: Farmers in Honduras evaluate different bean varieties. Credit: Bioversity International.

Abstract

Using on-farm triadic comparisons of technologies (tricot) for crowdsourcing participatory variety selection is a new citizen–science methodology for agriculture. Developed by Bioversity International as part of a programme known as Seeds for Needs, it allows large numbers of farmers to test different technologies on their farms. Farmers receive packages of seeds with a different combination of three different varieties, randomly selected from a large and diverse set of varieties to be tested. They submit their feedback in simple format, ranking the 'best / middle / worst' of each package for different traits. These farmer-generated data are then combined with environmental and socioeconomic data and analyzed with specific, novel statistical methods for ranking. Based on a review of several years of crowdsourcing experience in countries around the world, this report summarizes the different features and contributions of the tricot methodology to improve the functionality of seed systems.

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The report builds on research led by Jacob van Etten of Bioversity International, one of the pioneers and main developers of the TRICOT methodology. Jacob facilitated the interaction with the researchers who have experimented with the TRICOT methodology and with its data management platform. Several of them contributed to the review study.

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1. Introduction

Using on-farm triadic comparisons of technologies (tricot) for crowdsourcing participatory variety selection is a new citizen–science methodology for agriculture that has been developed by Bioversity International to make it possible for large numbers of farmers to 'massively test' different technologies (Beza et al. 2017; Steinke and Van Etten 2017; Van Etten et al. 2016). Tricot is part of a programme known as Seeds for Needs (see box) that is implemented by Bioversity International in countries around the world.

Seeds for Needs

Seeds for Needs is an approach for the demand-led introduction and testing of crop diversity that is underpinned by a number of methodological innovations. A first step in this approach is the identification of a range of varieties sourced from international and national genebanks, breeding programmes, community seed banks and farmers' fields that could potentially be adapted and acceptable in a given agroecological region. Farmers then test these varieties using a 'crowdsourced' citizen–science approach called 'tricot' (triadic comparisons of technologies), which supports the scaling of participatory evaluation using digital technologies and simple formats that allow unsupervised participation.

Farmers receive packages of seeds with a different combination of three different varieties (an 'incomplete block'), which allows a diverse set of varieties to be tested. They submit their feedback in simple format, ranking the 'best / middle / worst' of each package for different traits. These farmer-generated data are then combined with environmental and socioeconomic data and analyzed with specific, novel statistical methods for ranking. Using the tricot approach, it has been possible to demonstrate how varieties are differentially adapted to different growing conditions across large areas. It also allows the participation of many more farmers in participatory trials, which has a direct effect on variety dissemination.

The approach has been tested and documented in a series of peer-reviewed articles. A digital platform (ClimMob.net), an R package (PlackettLuce) and manuals and videos have been developed to support the method. The approach has already been adopted by a number of large-scale initiatives in South Asia, East Africa (e.g. the Integrated Seed Sector Development programme in Ethiopia supported by the Dutch government) and Central America.

The main idea behind recent citizen–science approaches is that large tasks can be accomplished by distributing small tasks to many volunteers and by combining the results. With tricot, the large task of variety evaluation is divided into many micro-tasks. Each farmer receives a combination of three technologies (for example, crop varieties or types of inputs) that can be tested and compared using a very simple on-farm trial format.

After more or less five years of piloting the new approach, this review, based on a desk analysis of articles written about the methodology, a survey and follow-up Skype calls, aimed to collect the perspectives from researchers using it in the field. Three questions were asked[1]

Does crowdsourcing participatory variety selection through on-farm triadic comparisons of technologies improve seed systems?

- What is its contribution to resilient seed systems?
- How do the various actors define its effectiveness?

One hundred forty-nine implementers and researchers were identified from a Google Group email address list of researchers having explored or used the ClimMob platform, a software application

1. See the review framework in Annex A.

used to process the data generated by tricot's on-farm trials. Some of them had also participated in training workshops.

Two-thirds of the respondents were from Bioversity International and the Integrated Seed Sector Development programmes managed by the Centre of Development Innovation of Wageningen University and Research, the Netherlands. The others were from institutions that were not identified. Ideally, it would have been useful to also collect the perceptions of the various categories of stakeholders involved in the methodology: implementers, researchers, facilitators and farmers. However, in the context of the present review, it was only possible to contact researchers, most of whom were also implementers.

In total, we received 10 contributions. A Spanish version of the questionnaire was also produced to try to elicit more responses from Spanish-speaking participants but did not lead to any additional replies. Observations and comments from the respondents were very relevant and even added elements that had not been reported in the articles reviewed.

Nine respondents out of the 10 contributors were or had been actively involved in organizing on-farm triadic comparisons of technologies. The other respondent was involved in the development of proposals for tricot, but was not involved directly in testing the approach. Two respondents mentioned some difficulty in answering the survey questions because they either did not have a lot of data or had encountered problems with the methodology.

This may be indicative of some of the reasons behind the low rate of response: the methodology itself being new and researchers not having sufficient experience with it to address the survey questions with confidence. In addition, as is the case in other surveys, the respondents' workload might also have played a role. In such contexts, face-to-face key informant interviews and field visits might be more suitable than an email survey.

It was therefore decided to do a number of follow-up Skype calls to request more complete responses and/or further elaborations of the answers given in the survey. The invitation was sent to all previously contacted researchers and implementers, with the objective of validating the survey's preliminary results and getting a better understanding of the challenges identified in implementing tricot (see Section 4). In total, six researchers participated in these follow-up interviews.

This report summarizes the different features and contributions of the tricot methodology outlined in the articles reviewed and identified in the replies to the survey and Skype calls. It should however be read with some caution, however, as it gives only a partial look at crowdsourcing participatory variety selection through on-farm tricot. This is due, on the one hand, to the low rate of responses and, on the other, to the absence of perspectives from participating farmers. The latter would require going to the field and meeting with farmers, which was not feasible for this review.

2. Does crowdsourcing participatory variety selection using tricot improve seed systems?

First, it enriches variety recommendations

The tricot methodology enriches variety recommendations and provides some solutions to some of the limitations of conventional practices.

- First, variety recommendations are often based on data that might not represent real conditions on farmers' fields. Seeds are usually tested in research stations or on demonstration farms. On research stations, farmers are not able to experience the new technologies; they only see the end product. On demonstration farms, they are able to see the new technologies but they are not there all the time, so there are still uncertainties about the management and external factors that influenced the technology during growth.
- Second, only a limited range of genetic materials reach farmers' fields, with elite material given preference and varieties from genebanks neglected.
- Third, variety recommendations are not specific enough to the areas where they are used.
- Last, the recommendations are seldom targeted at decreasing the risks to production that are related to climate (Fada and Van Etten, in press).

To overcome these barriers, the tricot methodology samples a wide range of farm conditions that actually occur locally. Farmers are able to compare three technologies and through this comparison learn more about the different characteristics that distinguish one variety from another. They can then choose the varieties they prefer. As one respondent puts it:

On-farm triadic comparison of technologies improves seed supply value chain by creating awareness of different varieties available to farmers.

New varieties can be tested in many different environments, under real-life farming conditions and can be matched to the environment where they are best adapted.

Second, it Improves on-farm testing

Current on-farm testing is usually done with a limited set of elite materials, which are compared to the current leading variety in the market. It requires constant attention from technical personnel, so, as a result, the testing is relatively costly, especially in marginal areas where technical personnel must travel long distances.

It allows the release of only a small number of varieties, backed by limited evidence of their value under actual farm conditions.

On the other hand, the tricot methodology was designed to overcome a number of specific challenges in participatory crop improvement, including the need for scaling, cost reduction and data standardization, taking into account heterogeneity in environments as well as farmers' preferences. It involves cost-effective, large-scale, repeated participatory evaluation of varieties under farm conditions using novel material from national genebanks or other sources (such as advanced lines from breeding programmes or varieties bred for other areas).

The methodology also ensures accuracy of its on-farm testing (Steinke, Van Etten and Zelan 2017):

TRICOT achieves external validity by placing crop varieties and other agricultural technologies directly in their target environment and by evaluating their performance in the eyes of the persons who will eventually adopt the technology or not.

Third, it engages and empowers farmers

Tricot also improves seed systems by increasing farmers' ownership of trials and supporting farmers' choices. It differs from the traditional 'push' approach from agronomists and extension agents to farmers and engages them directly in the decision-making process.

The use of improved or modern varieties often requires a large quantity of external inputs to fulfill their potential. On African low-input farms in high-risk areas, landraces may be preferred by local farmers because of their better adaptation, higher market value and better end-product quality. With tricot, participants can identify a variety they like and that fits the conditions on their farm.

As one respondent puts it:

I think it is of great importance that farmers can judge the performance of cultivars in their own field or field of neighbours. Otherwise they will be too much influenced by name and marketing strategies of new cultivars or they will stick to their traditional cultivars, which might not meet the requirement of markets or perform not sufficiently.

Engaging farmers directly in the development of new technologies has many benefits. It decentralizes efforts at crop improvement, reduces costs, enhances the efficiency of plant breeding and shortens the time frame for new varieties to be released. It also increases adoption rates, and allows the adoption of a portfolio of varieties that will enhance resilience in the face of climate unpredictability. What is perhaps most important, it will maximize yields at any given location rather than promoting a good average variety.

The model also provides information to breeders about the needs and preferences of farmers so the seed system can be (re)focused on farmers' preferences instead of on researchers' choices, which might not be in line with what farmers are most interested in.

Fourth, it contributes to a diversification of seed systems

The tricot methodology is also an alternative to conventional practices because it supports farmers' on-farm selection of varieties on the basis of seed performance in different agroecological and climatic zones of a given country.

One researcher gave the example of Ghana where official cacao variety recommendations are made exclusively at the national level by the Cocoa Board of Ghana (COCOBOD) without much attention given to specific agroecological regional situations and farmers' needs. In this case (still at the proposal stage), the tricot methodology would give farmers the opportunity to recognize the differences between varieties (empowering them) and to make their own selection.

Another researcher gave an example from Ethiopia where many varieties released by different research centers are not in the hands of farmers. With the participatory crowdsourcing approach, at least eight varieties of a single crop were introduced. They were assessed both through participatory variety selection (PVS) at farmer training centers and through tricot with 200 farmers. Farmers were able to select the best varieties and have started to multiply them and hand them over to other farmers. This is improving the informal seed system through exchange and purchase of these varieties among farmers. The researcher remarked:

This way, the farmers got an opportunity to access different varieties of different crops. This has improved the informal seed system, which comprises 90% of the seed system, through exchange and purchase of the varieties among farmers.

The approach has the potential to contribute to making seed systems more dynamic. It can also contribute to the efficiency of the informal seed sector by including local cultivars that might have promising traits necessary for climatic adaptation, but that might be lost if their seeds are not

shared and tested in broader environments. New cultivars coming from research stations can also be included and tested under real-life conditions in farmers' fields.

The methodology strengthens the existing local seed supply chain through providing alternative seed sources and giving a large number of farmers access to different seeds so they can select their preferred varieties.

It also creates the space for an intermediate seed system in which local seed cooperatives or community seed banks are involved in the production of preferred seeds identified through tricot. There is space for this as new legislation is being developed in Africa (including Tanzania, Uganda and Ethiopia) in which rules about seed production allow local actors to multiply and sell seeds of certain varieties of sufficiently good quality (quality declared seeds, QDS).

Fifth, it supports scaling

The tricot methodology also improves seed systems by supporting scaling of on-farm agricultural research. As one respondent states:

It is a much easier approach to upscale as seed distribution and assessment is easier and data can be added electronically.

The tricot methodology allows information-based tasks to be scaled to new levels that were not possible before. By giving farmers different, partially overlapping combinations of technologies, larger sets of technologies can be compared: for example, sets of 10-20 crop varieties. A large number of farm households can be involved in the approach, which can help to overcome the limited scalability and free-rider problem in existing participatory methodologies.

Of course, scaling depends on reliability and the validity of data generated by farmers. On this, tricot research has shown the following (Steinke, Van Etten and Zelan 2017):

Low reliability of farmers is no hindrance to obtaining statistically significant and relevant results. Our results show that, in aggregate, the observations contain sufficient information […] [and] sufficiently large numbers of observers can compensate low reliability, i.e., when the consensus of this large group converges on the correct answer. This means that scaling on-farm agricultural research by a crowdsourcing methodology is feasible.

Sixth, it enables women to do their own variety selection

One interesting feature of the methodology, identified in the replies to the survey and in the Skype interviews, is its gender-responsiveness. Women are empowered by participating directly in agricultural research. With tricot, because each farmer selects and scores varieties, women can select the ones they prefer. This is an alternative to conventional selection approaches where all farmers do the selection together and women might not always be able to fully participate, speak up or vote for their preferred variety or varieties.

This positive aspect has not been explored very much in the literature reviewed, but some analysis is under way (J. van Etten, personal communication).

Seventh, it offers business opportunities for farmers, women and young people

An indirect contribution to the improvement of seed systems is the opening of seed-related business opportunities. As farmers get actively involved in cultivar testing, they also build confidence in their own observations, and some of them might start multiplying their own seed or even start a local seed business to supply seed to their neighbours. Some farmers may even be interested in getting more involved in breeding,

A decentralized production of seed and seedlings at the farm level can also empower women and young nursery managers and bring adapted varieties closer to the region where they are needed. In Ghana for example, cacao seedpods are produced by the national system, which is starting to look at privatization of the provision of seedlings. This offers new opportunities for farmers and seedling producers. It is expected that by using the tricot methodology and working with women's associations and young people, the development of businesses in the cacao seedlings sector will be encouraged.

Eighth, it gets researchers to learn farmers' variety preferences

Tricot can also be a helpful tool for researchers. By offering a streamlined process – from research design, data collection and analysis to feedback delivery – it supports field agents and researchers in their work and allows them to collect data on-farm from large numbers of farmers.

This can help researchers test technologies in many different locations, and collect data on the factors that define the performance of these technologies. By analyzing these data, they will learn which seeds perform better in which kind of context and which seeds are preferred by farmers. Targeting can be improved as a result.

3. What is tricot's contribution to resilient seed systems?

First, it delivers variety recommendations for risk-reducing portfolios

Tricot has the potential to significantly contribute to the improvement of seed systems by allowing the delivery of varieties based on seasonal climate forecasts or on prevailing conditions in different environments. It also provides a bottom-up, data-intensive approach to adapting to climate change.

At present, actual practices largely fail to insert varietal diversity for adapting to climate change into local farming systems in a rational way.

Because it combines variety evaluation data with environmental data, tricot can measure the responses of crop varieties under seasonal climatic conditions. It can also determine if varieties perform differently under different environmental conditions.

In addition, since field trials permit the identification of seeds adapted to vulnerable climate conditions, the resilience and production of a given crop should improve because of the use of varieties that are better adapted to regional agroecological and climatic conditions.

As described by two pioneers of the methodology (Fada and Van Etten, in press):

Combining the resulting geo-referenced variety evaluation data with environmental data and climatic data, the approach distinguishes different responses of crop varieties to seasonal climatic conditions. The data can then be translated into concrete variety recommendations that reflect current farm conditions, stabilize yields, and track climate change over time.

Second, it reduces vulnerability

At the same time, the tricot methodology contributes to strengthening local seed systems because more choices are available to adapt to climate change and because farmers are empowered to make their own choices by learning which varieties work in their specific climate zones.

By involving large numbers of farmers in the trials, tricot also facilitates the distribution of technology, which reinforces the local seed system.

The tricot methodology also reduces vulnerability by teaching research skills to farmers, skills that they can later transfer and use in adjusting to changing climate conditions.

4. How do the various users define its effectiveness?

According to the literature, the effectiveness of tricot is characterized by the following:

- The distribution of trial packages and instruction sessions is relatively easy to execute.
- Farmers do not need to be organized in collaborative groups.
- Feedback is easy to collect, either on paper or by phone.

Respondents also add that tricot is an effective tool for reaching many farmers with many crops in a short time. For farmers, it is a good way to become familiar with new varieties, to increase their knowledge and skills and to identify the most adaptable varieties. Apart from the selection of improved materials, it also leads to speeding up variety release because farmers who select a new variety start producing seed for it.

According to the literature and to some of the respondents, the approach is simple to implement with limited resources. All that is needed is to set aside a small proportion of land for testing and collect the data. This makes it a more effective approach when compared to others that evaluate new technologies in groups on communal or rented land.

At the same time, some challenges were identified.

Training and preparation

A few respondents mentioned that the methodology was training intensive, requiring efforts and investments from the implementers (in time, organizational and financial resources) and from the farmers (mostly in terms of time).

It is true that from the point of view of an implementer, preparing the trials and organizing training for local facilitators as well as for a large number of farmers can be a challenge. There are costs and logistics involved in getting all the participating farmers in the same place for training. In remote areas, participants who come from afar may sometimes arrive at the meeting at different times, which complicates the situation.

Preparation can also be demanding. One researcher estimated the time needed to put things in place at one and a half to two months.

A researcher who has organized trials for 1,500 farmers mentioned the importance of working with groups that were already organized. Such groups are already familiar with agricultural experiments and the organization involved. There are also already experienced people who can supervise the trials and do the follow-up. In the absence of such groups and trained collaborators, the training and preparation can be demanding.

In the case of implementers who work with small numbers of participants (20 per village), organizing training does not seem to be such an issue. One implementer explained that they proceed with one introductory visit in each village, where they explain the process and ask who wants to participate. Then they hold a training workshop of three or four hours in the field, and have a third meeting to share the global results after the trials. Likewise, training for participating technicians also takes some three hours.

Apart from the preparation itself, it seems that the main difficulty encountered by researchers implementing tricot is related to the socioeconomic conditions of subsistence farmers in different regions, not to the training itself.

In some contexts, where political polarization is high, some families might not want to participate if other families do, or the community leader might also interfere with the participation of some selected farmers. In some cases, security issues also play a part in moving from one zone to another.

In contexts where the work is done in remote areas with poor, subsistence farmers, it can also be challenging to ensure that all the farmers understand the methodology. Sometimes, it is a question of language and vocabulary; other times it can also be a question of comprehension.

One respondent mentioned that the main difficulty related to training, especially when working in remote areas, was to explain things in a way that makes sense for participants. In some areas, the rate of illiteracy is high and presents a real challenge. Not everyone can easily understand the concept of a trial, for example, or relevant agronomical information, or even recognize that farmers themselves can evaluate a variety.

In some cases, malnutrition and extreme poverty may even have affected the intellectual capacity of some participants. 'Sometimes some farmers are not able to distinguish between the three technologies experimented and they rate them all equally,' mentioned one researcher.

Such difficulties are not specific to tricot. The same can be said for all new methodologies, especially participatory methodologies. They do require some time for preparation and training, and are subject to the same limitations when applied in difficult contexts.

One respondent mentioned that in his region, a farmer's organization was taking responsibility for training and for conducting participatory breeding and cultivar testing independently from researchers or facilitators. This could be another option for addressing the organization challenge.

Another researcher also mentioned that her organization was planning to experiment with a condensed training formula that would be more effective.

Changes in attitudes

One respondent mentioned that planning trials with a large number of farmers demanded some changes in attitude. Field staff and national researchers, in particular, need to move from top-down implementation to a more bottom-up approach. This can vary from one implementing institution to another. Some researchers and extension agents still adopt a superior stance when interacting with farmers. The same can be said also of lead farmers who want to preserve their status.

Implementers and field staff need to carefully assess which data are useful in the experiments (and adopt a 'less is more' approach) since they rely on farmers to collect the data.

Gender considerations

Most of the respondents mentioned that tricot enables women farmers to select the varieties they prefer, because choices are made on an individual basis. This is certainly an improvement compared to other participatory approaches to variety selection that use groups.

As one respondent mentioned:

In the traditional method, all farmers select together, which was not good to women because in many of our culture women cannot talk in front of men, but in crowd sourcing each farmer selects and scores a variety alone.

When the woman is with her husband, she will say nothing, said another.

This is particularly important in the case of crops that are mainly the responsibility of women. Furthermore, in some traditional societies, where women are responsible for housework, they will use other criteria than men to judge a given variety, such as the taste, how it is cooked and can be preserved, the quantity needed to prepare a meal, or criteria related to the performance of the variety in a small garden.

Another advantage for women with tricot is that they can experiment with the technologies on a small plot of land not far from their house. This is a big advantage compared to other methodologies where they need to go to the field.

Two respondents indicated that the approach was not designed with a focus on women, and that there were still hurdles to overcome for female participants. 'Land ownership would be one of them, but there are many more,' mentioned one respondent. Working on a male-oriented crop, having less time to experiment because of domestic duties, being able to participate in the research itself are other hurdles that can limit women's participation. However, these structural difficulties are not specific to this methodology.

Other gender considerations have been raised in the literature. Pilot projects have shown that bringing women's participation to a level equal to that of men requires special recruitment efforts. Again, this is not specific to the tricot methodology and can be observed in many settings. It also depends on the cultural context of each region. Within the same country, in some regions women may be able to speak for themselves and take their own decisions but not in others. And within the same region, the situation might be very different for subsistence farmers than for others.

Another issue may be the technologies chosen for experimentation, e.g. varieties of the main staple crops. If they were linked more specifically to domains that women tend to manage (such as food processing or kitchen garden crops), could it contribute to an increase in women's participation?

On a related aspect, one researcher suggested adding more illustrations of women and children on the material used by the farmers. She explained that in some remote areas, where there is high illiteracy, children are often asked by their parents to fill in the forms and that it is a gender aspect that should also be taken into consideration.

Impact of climate change

Another challenge identified is due not to the methodology itself, but to its application in the context of climate change. Sometimes there are external challenges that can limit the methodology's application. In one case, in a region affected by drought, only 23 farmers of a total of 73 participants had results after 45 days, and only 4 had results after the 60-day trial.

Technology

Technology is a pillar of the tricot methodology. From the replies to the survey, it seems that there might be some issues related to this that merit more attention. Three implementers mentioned problems in collecting results from farmers due to difficulties with mobile communication.

This needs to be better understood. Usually, participating farmers do not communicate results directly to implementers. Lead farmers collect the data from participating farmers and communicate the results to the implementers. In general, they are trained and have experience in sharing the results by mobile. (In one case, it was mentioned that older lead farmers were not comfortable with the use of mobiles and had asked younger ones to share the results, but this seems to be the exception.)

However, at least in two situations reported by the respondents, implementers did collect feedback directly from the participants. In one case, it reflects the choice made by the research organization and may signal a misunderstanding of the methodology. In the other case, it was context related. The researchers were working with women from subsistence farming families who had no access to the mobile phones owned by their husbands. They had to organize visits by technicians in every village to collect the assessment forms, which involved costs and logistics that had not been planned on.

The fact that mobile communication does not work very well in some remote areas was also reported. At least in one case, the implementer had difficulties receiving any information from the lead farmers by mobile phone. The collection of printed forms can compensate for such difficulties, but it is a lengthier process, and in areas with high rates of illiteracy, which often coincides with remote areas, the information obtained through printed forms is not always very reliable.

Difficulties are not always due to the technology itself. As one researcher mentioned, 'We cannot always be sure that the lead farmer has really met with all participating farmers.'

Regarding the use of ClimMob, the platform used by implementers to combine and treat farmers' generated data, only five respondents mentioned using it, and they all experienced some problems. One respondent said it needed to be more user-friendly, especially regarding the interface of version 3. Another thought most problems were related to the network in their country, not necessarily to the platform itself. For a third, the tool needed more rigorous testing in field conditions, especially in sub-Saharan Africa, in zones with limited Internet connections. A fourth implementer had problems in updating the data previously registered in their ClimMob project. Finally, one researcher mentioned that when the name of a participant is written with capital letters and elsewhere without, or with a spelling mistake, the software treats it as two different persons and divides the data between the two entries. Cleaning up these duplications can be a very lengthy process.

One respondent, working in an agricultural research institution actually experienced with tricot, explained that researchers do not use ClimMob because it doesn't allow them to compare each attribute between local and imported varieties (the version they use only allows a global comparison between varieties). In their case, they reformatted the printed data collection forms and have facilitators fill them in by interviewing participants on each farm and observing whether all the conditions are respected. This of course limits the potential of the methodology.

Other issues

The literature on tricot also mentions the following:

- There is a risk that some or all participants will find none of the tested varieties better than their own.
- If the number of farmers reporting data is too low, the project may yield results that are not useful for the researchers, although the trials can still be useful to farmers.
- Varieties developed or identified through participatory methods need to spread to other farmers. In the absence of a formal system for seed delivery, the capacity for spreading varieties should not be simply assumed.

A limitation of the current pilots is that many farmers have had general experience in participatory varietal selection or participatory research. Future studies need to expand to communities without any experience in participating in participatory variety trials in order to evaluate their reception of the approach.

5. Conclusion

This desk study aimed to identify the strengths of crowdsourcing (and citizen science) through on-farm triadic comparisons of technologies (tricot) to improve the functionality of seed systems and to provide suggestions for scaling. A desk review complemented by a survey explored three research questions:

- Does crowdsourcing participatory variety selection through on-farm triadic comparisons of technologies (tricot) improve seed systems?
- What is the contribution of the methodology to resilient seed systems?
- How do the various actors define its effectiveness?

The results identified the characteristics discussed below.

Tricot contributes to the improvement of seed systems in many ways: enriching variety recommendations, improving on-farm testing, engaging and empowering farmers, contributing to the diversification of seed systems, supporting scaling, enabling women to do their own variety selection, offering opportunities for local seed businesses and getting researchers to learn farmers' variety preferences.

Regarding tricot's contribution to resilient seed systems, the approach contributes to strengthening local seed systems because more choices are available to adapt to climate change and because farmers are empowered to make their own choices by learning what varieties work in their specific climate zones. Since field trials permit the identification of seeds adapted to changing climate conditions, the resilience and production of a given crop should also improve, based on the use of varieties more adapted to regional agroecological and climatic conditions.

Regarding tricot's effectiveness, the approach seems simple to implement with limited resources. However, certain difficulties where identified and need to be better understood. In terms of technology, problems associated with limited mobile connections in some remote areas or with costs related to the use of mobiles need to be examined. Newer versions of ClimMob should also facilitate comparisons of each attribute between local and imported varieties.

In terms of farmers' engagement, the integration of gender considerations in the approach could be made more explicit, and ways to increase gender responsiveness identified. For example, in a pilot project in India, involving self-help groups of women increased women's participation. Difficulties related to preparation and training where no groups have already been organized or in the context of high rates of illiteracy could also be explored.

Another aspect that could be improved is the feedback given to farmers after experimentation, which, in some cases, might be omitted or limited in the handing of a sheet of summarized results to farmers. There seems to be a need to improve the design of that crucial phase of experimentation.

Some researchers also think that the methodology could be improved by allowing the farmers to ask for technologies to experiment with. Tricot could evolve by having a demand-driven dimension. This would require specific pilots to design and monitor the process.

There would be much more to report on the tricot methodology, however, if the most important actors in tricot were interviewed: the farmers. Before suggesting scaling actions, this report would recommend more research through field visits and interviews with key informants.

Another aspect of the desk study is that it focused on improving the functionality of seed systems through crowdsourcing (and citizen science) using tricot. It could be useful to include – and learn from – lessons from other citizen science approaches in the plant sciences (for example, the one used in the 1000 Gardens project) documented in the articles reviewed for this study.

In comparison with other participatory methodologies engaging farmers in plant variety selection, tricot involves large numbers of farmers living in different environments, who are able to experiment

directly with different technologies, choose the most appropriate ones for their own local context (based on their own preferences) and disseminate them. This by itself is a methodological advance that contributes to plant variety selection and the improvement of seed systems.

The contribution of the tricot methodology for improving seed systems and building resilience to face the realities of climate change has been reported in the literature and raised in the contributions of the respondents to our survey. Evidence of the feasibility of the approach (technological, economic, social and environmental) has also been reported in the articles reviewed for this exercise. A better understanding of the nature and scope of the problems identified in implementing tricot and of ways of nurturing the changes of attitudes needed from researchers and extension agents to implement such an innovative approach will help reinforce this contribution of citizen science to agricultural research.

Bibliography

Barrios Aguirrez A, Aguilar Carrillo A (2018) Aprendizajes sobre la implementación de la metodología de Evaluación Participativa Masiva (EPM). Unpublished ms.

Beza E, Steinke J, Van Etten J, Reidsma P, Fadda C, Mittra S, Mathur P, Kooistra L (2017) What are the prospects for citizen science in agriculture? Evidence from three continents on motivation and mobile telephone use of resource-poor farmers. PLOS ONE 12(5).

Fada C, Van Etten J (in press) Generating farm-validated variety recommendations for climate adaptation. The Climate Smart Agriculture Papers, eds Rosenstock T, Nowak A, Girvetz E (Springer, Cham), pp 127–138. DOI: https://doi.org/10.1007/978-3-319-92798-5_11

CGIAR (2017) Grain Legumes and Dryland Cereals (GLDC), Unlocking Markets, Improving Livelihoods, Full Proposal. (CGIAR, Montpellier).

Ojiewo C, Essegbemon, A, Njuguna-Mungai, E, Muricho, G. (August 2018) Grain Legumes and Dryland Cereals (GLDC), Seed Systems Data Tool (ICRISAT, Hyderabad).

Ojiewo C, Essegbemon, A, Njuguna-Mungai, E, Muricho, G. (2018) Review of the status of seed value chains of CRP-GLDC target crops in East Africa. Background document of qualitative and quantitative data collection for GLDC Seed System (ICRISAT, Hyderabad).

Steinke J, Van Etten J (2017) Gamification of farmer-participatory priority setting in plant breeding: Design and validation of "AgroDuos". Journal of Crop Improvement 356-378. Online (accessed 2018): www.bioversityinternational.org/e-library/publications/detail/gamification-of-farmer-participatory-priority-setting-in-plant-breeding-design-and-validation-of-a/.

Steinke J, Van Etten J (2016) Farmer experimentation for climate adaptation with triadic comparisons of technologies (tricot), A methodological guide (Bioversity International, US Aid, CGIAR-CCAFS).

Steinke J, Van Etten J, Mejía Zelan P (2017) The accuracy of farmer-generated data in an agricultural citizen science methodology. Agronomy for Sustainable Development 37(4).

Van Etten J (2017) Crowdsourcing crop improvement in Sub-Saharan Africa: A proposal for a scalable and inclusive approach to food security. IDS bulletin.

Van Etten J, Steinke J, Van Wijk MT (2017) How can the Data Revolution contribute to climate action in smallholder agriculture? Agriculture for Development 30.

Van Etten J, Bezza E, Calderer L, Van Duijvendijk K (2016) First experiences with a novel farmer citizen science approach: Crowdsourcing participatory variety selection through on-farm triadic comparisons of technologies (tricot). Experimental Agriculture, First View, pp 1–22. DOI: https://doi.org/10.1017/S0014479716000739.

Würschum T, et al. (2018) The soybean experiment '1000 Gardens': A case study of citizen science for research, education, and beyond. Theoretical and Applied Genetics (2018). DOI: https://doi.org/10.1007/s00122-018-3134-2.

Annex A – Review Framework

The survey sent to respondents was based on the following review framework:

Does crowdsourcing participatory variety selection through on-farm triadic comparisons of technologies improve seed systems?

- What is the perception of the various categories of stakeholders involved in the methodology (improvement of seed systems)?
    * Implementers
    * Researchers
    * Facilitators
    * Farmers
- How does it provide an alternative to the conventional seed supply chain? What does it add to traditional approaches?
- How does it improve the various elements of the seed system from field selection of seeds all the way down to seed distribution?

What is its contribution to resilient seed systems?

- Does it support the ability of seed-system actors to absorb disturbances and adapt to changes caused by a perturbation?
- Does it facilitate multiple seed and knowledge interactions and continuous learning among seed-system actors and related institutions?
- Is it demand-driven and responsive to differentiated needs and interests, supporting all users and farming systems?
- How does it recognize, respect and support the key roles played by women farmers as seed custodians, managers, networkers and entrepreneurs?
- How does it contribute to reducing vulnerability?
    * Assuring access to seeds in terms of affordable price and when needed?
    * Assuring availability in terms of production and distribution?
    * Guaranteeing seed quality in terms of adaptability, safety and longevity and seed responsiveness and supportiveness of actions to adapt to climate change?
    * Guaranteeing seed diversity?
    * Helping produce crops for a healthy diet?
    * Contributing to the recognition and respect of seed as social and spiritual capital and not only physical capital?
    * Other?

How do the various actors define its effectiveness?

- What are the changes observed by each category of stakeholders

(traditional distribution of varieties, participatory selection, etc.)?

    * Implementers
    * Researchers
    * Facilitators
    * Farmers

- How do they describe the effectiveness, usefulness and potential of the methodology?
    * Better selection of superior materials
    * Better location-specific variety recommendations (climate, culinary, culture, management, etc.)
    * Speeding up variety release
    * Starting dissemination earlier
    * Speeding up adoption
    * Providing more benefits to farmers
    * Etc.
- What are the difficulties they encounter with the methodology or with the tools (forms, ClimMob platform, Google group)?
- Who uses the ClimMob platform and how do they assess its user-friendliness?
- What do non-users say about the platform?
- Have farmers adapted the methodology to their own needs In some cases?

About CRP-GLDC

The CGIAR Research Program on Grain Legumes and Dryland Cereals (CRP-GLDC) brings together research on six legumes (chickpea, cowpea, pigeonpea, groundnut, lentil and soybean) and three cereals (pearl millet, finger millet and sorghum) to deliver improved livelihoods and nutrition by prioritizing demand driven innovations to increase production and market opportunities along value chains.

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CGIAR is a global research partnership for a food-secure future. CGIAR science is dedicated to reducing poverty, enhancing food and nutrition security, and improving natural resources and ecosystem services. Fifteen CGIAR Centers in close collaboration with hundreds of partners, including national and regional research institutes, civil society organizations, academia, development organizations, and the private sector carry out its research.

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